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(12) United States Patent
Holden

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(54) **INDENTED TUBE FOR A HEAT EXCHANGER**

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B21C 37/20 (2006.01)
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CPC ***B21C 37/158*** (2013.01); ***B21C 37/15*** (2013.01); ***B21C 37/202*** (2013.01); ***B21D 17/02*** (2013.01); ***B21D 53/06*** (2013.01); ***F28D 7/16*** (2013.01); ***F28F 1/006*** (2013.01); ***F28F 1/025*** (2013.01); ***F28F 1/06*** (2013.01); ***F28F 1/42*** (2013.01); ***F28F 1/426*** (2013.01); *F28D 21/0003* (2013.01); *F28F 2210/06* (2013.01)

(58) **Field of Classification Search**
CPC B21C 37/158
USPC 72/370.16, 370.19, 370.21, 77, 78, 98, 72/370.12, 370.13, 367.1, 368, 80, 95, 72/100, 370.04, 370.14, 370.23, 370.24, 72/370.25
See application file for complete search history.

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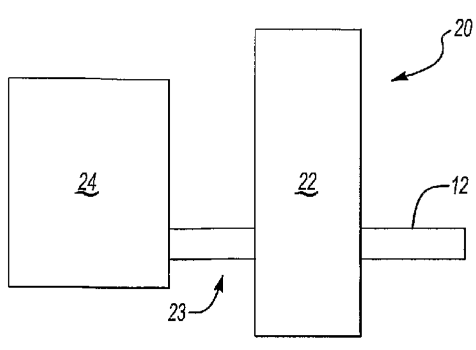
(57) **ABSTRACT**

A shell tube and heat exchanger (**10**) includes a plurality of tubes surrounded by a shell (**16**). Each tube (**12**) includes a plurality of indentations. A mold is placed in a desired positions and orientation in a die. A tube is placed in a first position within a die, and the mold crimps the tube to form the desired indentation in the tube. The mold is then released, and the tube is moved relative to the mold to a second position. The mold again crimps the tube to form an additional indentation. Alternately, the mold includes a roller that forms a groove on the tube. The tube is translated or both translated and rotated relative to the mold to form the groove.

7 Claims, 4 Drawing Sheets



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B21D 17/02	(2006.01)
B21D 53/06	(2006.01)
F28D 7/16	(2006.01)
F28F 1/00	(2006.01)
F28F 1/02	(2006.01)
F28F 1/06	(2006.01)
F28F 1/42	(2006.01)
F28D 21/00	(2006.01)

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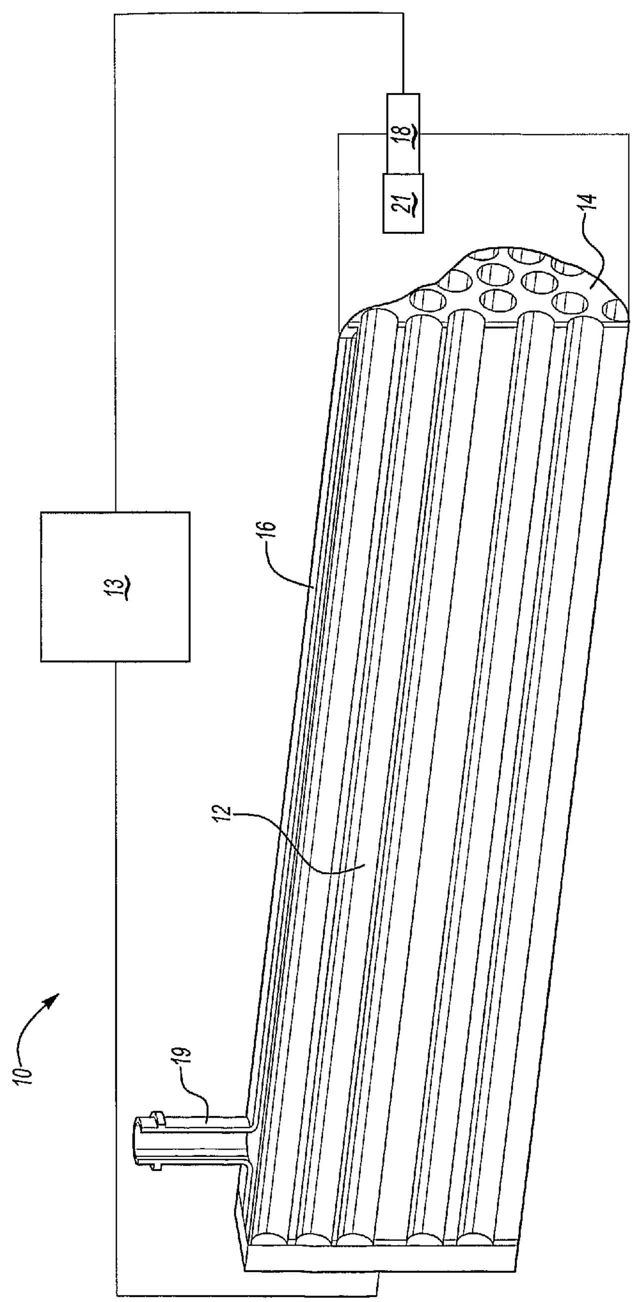

Fig-1

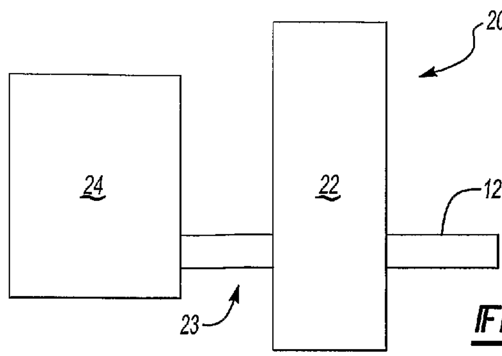

Fig-2

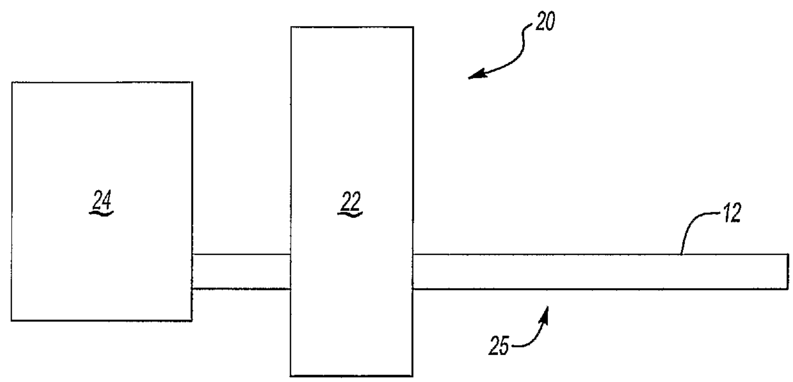

Fig-3

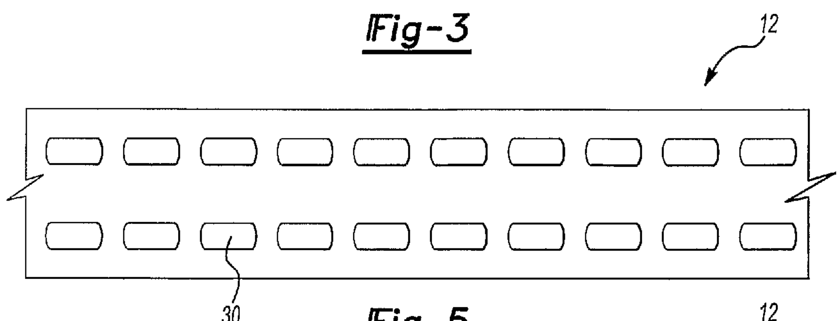

Fig-5

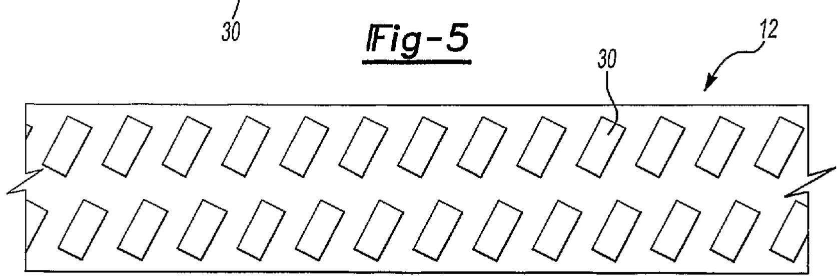

Fig-6

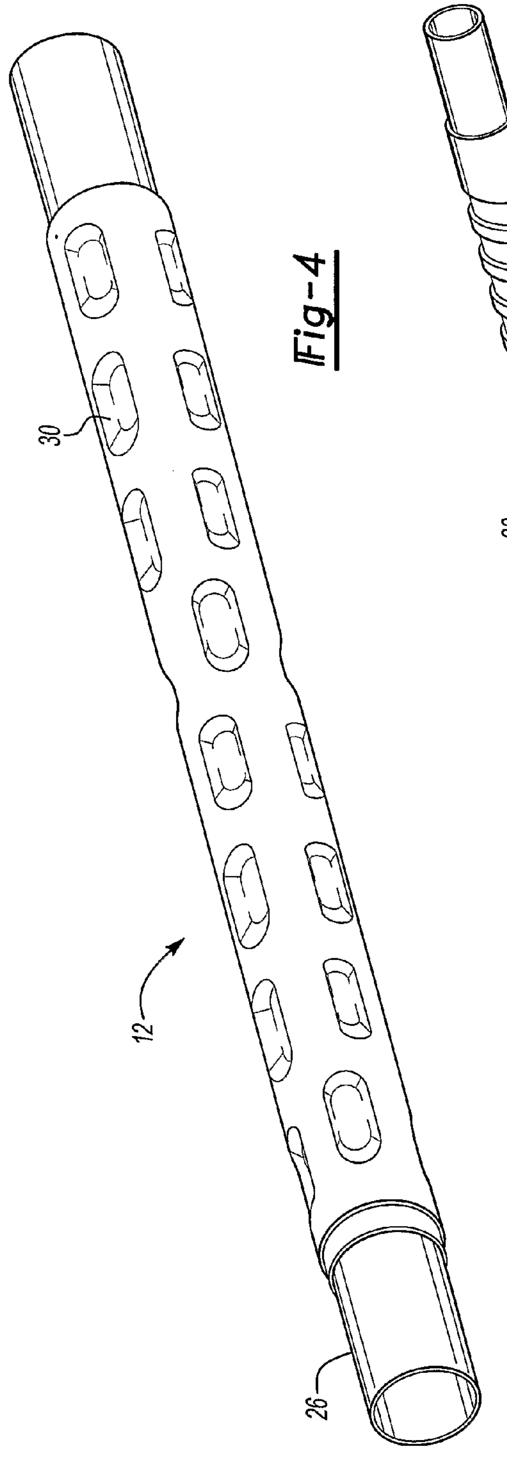

Fig-4

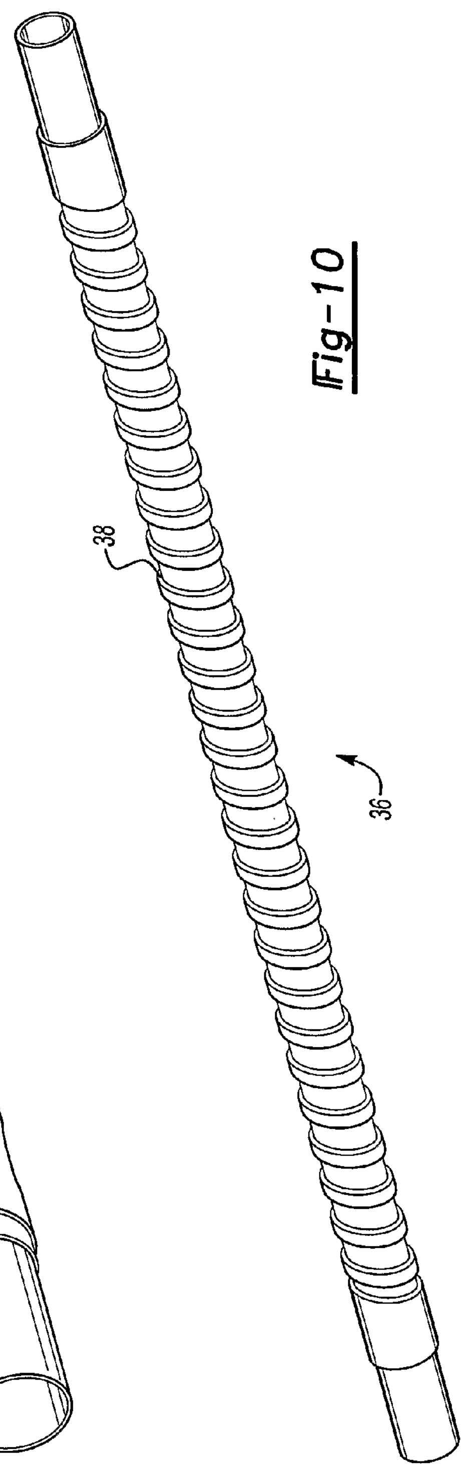

Fig-10

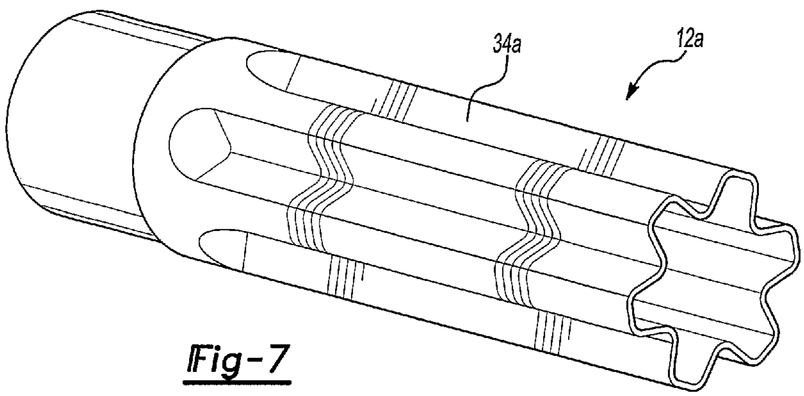

Fig-7

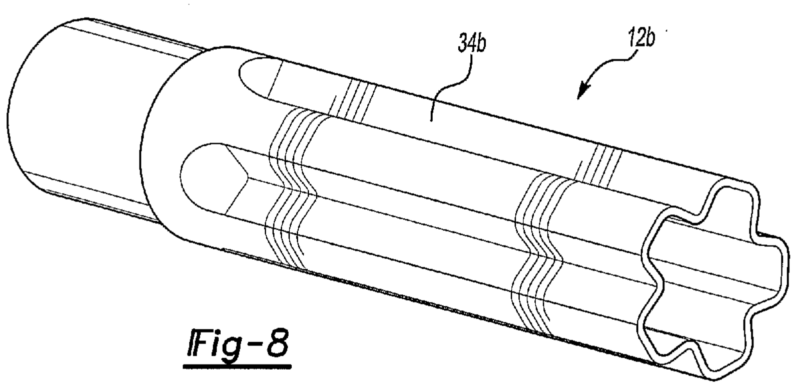

Fig-8

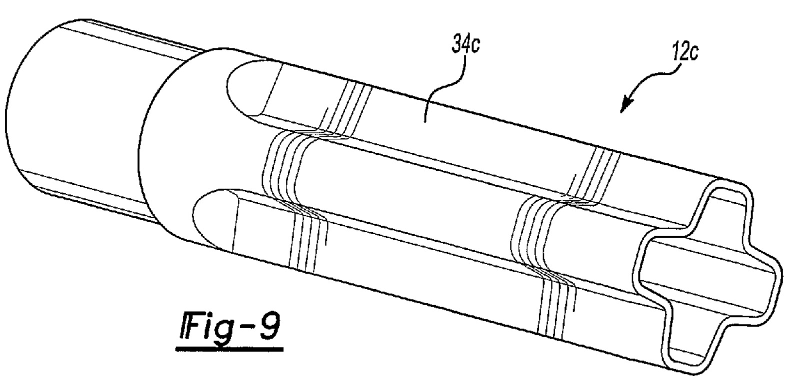

Fig-9

INDENTED TUBE FOR A HEAT EXCHANGER

BACKGROUND OF THE INVENTION

The present invention relates to a method for forming a tube used in a heat exchanger including a plurality of indentations that increase heat transfer between a fluid flowing through the tube and a fluid flowing around the tube.

A shell and tube heat exchanger is used to cool fluids in various automotive applications, including exhaust gas recirculation coolers and power steering devices. In an engine gas recirculation system, an exhaust fluid flows inside the tube and exchanges heat with a coolant flowing around the tube. The exhaust fluid closer to the tube wall cools faster than the exhaust fluid flowing in the center of the tube.

In the prior art, the tubes in the heat exchanger can be bent or twisted to create turbulence in the exhaust fluid and to provide a non-linear flow path to increase heat transfer.

There are several drawbacks to the bent or twisted tubes of the prior art. For one, it is difficult to manufacture the tubes. Additionally, it is both costly and laborious to twist and bend the tubes to the desired shape.

Hence, there is a need in the art for a method for shaping a tube used in a heat exchanger that overcomes the drawbacks and shortcomings of the prior art.

SUMMARY OF THE INVENTION

A shell and tube heat exchanger includes a plurality of tubes surrounded by a shell. Each of the tubes includes a plurality of indentations. A cooling fluid flowing through the shell exchanges heat with a hot fluid flowing through the tubes. Preferably, the shell and tube heat exchanger is used in an exhaust gas recirculation system, and an exhaust fluid flows through the tubes and exchanges heat with a coolant flowing through the shell.

The tube includes indentations that increase the surface area of the tubes and the amount of fluid located proximate to the walls of the tubes. The indentations also create turbulence in the fluid flowing through the tubes.

In one example, a mold of a desired shape is placed in a desired position and orientation in a die. The tube is placed in a first position within the die, and the mold crimps the tube to form the desired indentation in the tube. The mold is then released, and the tube is moved relative to the mold. The mold then again crimps the tube to form an additional indentation. The tube can be translated relative to the mold or can be both translated and rotated relative to the mold.

Alternately, the mold includes a roller that forms parallel grooves on the tube. The tube is translated relative to the mold to form the grooves on the surface of the tube. The number of rollers determines the number of grooves. Alternately, the tube is both translated and rotated relative to the mold to form a spiral groove on the surface of the tube.

These and other features of the present invention will be best understood from the following specification and drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** illustrates a cross-section of a shell and tube heat exchanger;

FIG. **2** illustrates a die for molding a tube of the present invention in a first position;

FIG. **3** illustrates the die for molding the tube in a second position;

FIG. **4** illustrates a perspective view of a first embodiment of the tube including angled indentations;

FIG. **5** illustrates a perspective view of the first embodiment of the tube including parallel indentations;

FIG. **6** illustrates a perspective view of the embodiment of the tube including different angled indentations;

FIG. **7** illustrates a cross-sectional view of a second embodiment of the tube including six grooves;

FIG. **8** illustrates a cross-sectional view of the second embodiment of the tube including five grooves;

FIG. **9** illustrates a cross-sectional view of the second embodiment of the tube including four grooves; and

FIG. **10** illustrates a perspective view of a third embodiment of the indented tube including a spiral shaped groove.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

FIG. **1** illustrates a shell and tube heat exchanger **10** including a plurality of tubes **12** surrounded by a shell **16**. Opposing end portions **26** of the tubes **12** are attached to a plate **14**. The end portions **26** of the tubes **12** can be attached to the plate **14** by welding, press-fitting, or by any other means of attachment. A cooling fluid enters the heat exchanger **10** through an inlet **18** located at one end of the heat exchanger **10**. The cooling fluid flows through the shell **16** and exchanges heat with a hot fluid that flows through the tubes **12**. The fluid in the shell **16** exits the heat exchanger **10** through an outlet **19**.

If the heat exchanger **10** is used with an exhaust gas recirculation system, an exhaust gas recirculation valve **21** controls the flow of hot fluid from an engine **13** or other component into the heat exchanger **10**. If the heat exchanger **10** is used in an exhaust gas recirculation system, the hot fluid is an exhaust fluid. The hot exhaust fluid enters the tubes **12**, and heat is transferred from the hot exhaust fluid to a coolant flowing in the shell **16** surrounding the tubes **12**. The cooled exhaust fluid in the tubes **12** is then recirculated to the engine **13** or other component. Although an exhaust gas recirculation system has been illustrated and described, it is to be understood that other applications utilizing a tube and shell heat exchanger **10** may also use the tubes **12** of the present invention.

The tubes **12** include a plurality of indentations **30** that increase the surface area of the tubes **12**, the amount of hot fluid that is proximate to the walls of the tubes **12** to increase the heat transfer, and the amount of turbulence in the fluid in the tubes **12**. Creating turbulence in the hot fluid within the tubes **12** mixes the fluid in the center of the tube **12** and the fluid proximate to the walls of the tube **12**. Thus, the fluid proximate to the walls of the tube **12** will continually change as the fluid circulates and flows through the tubes **12**.

FIGS. **2** and **3** illustrate the method of forming the tube **12** of the present invention. A mold **22** of a desired shape is placed in a desired position and orientation in a die **20**. The tube **12** is positioned in a first position **23** within the die **20**. The mold **22** then crimps the tube **12** to form an impression or indentation **30** in the tube **12**. The mold **22** is then released. A moving device **24** both rotates and translates the tube **12** relative to the mold **22**. Once the tube **12** is in a second position **25**, as shown in FIG. **3**, the mold **22** again crimps the tube **12** to form an additional indentation **30** in the tube **12**. The process of translating and rotating the tube **12** and using the mold **22** to crimp the tube **12** may be repeated as many times as needed to form the desired number and orientation of indentations **30** in the tube **12**.

FIG. **4** shows a first embodiment of the tube **12** of the present invention. The mold **22** crimps the tube **12** to form indentations **30** in the tube **12**. The mold **22** is released from the mold **22**, and the tube **12** is rotated and translated relative to the mold **22**. The mold **22** then again crimps the tube **12** to form an indentation **30**. In one example, the tube **12** is rotated approximately 5 and 10 degrees between successive crimps.

Alternately, shown in FIG. **5**, the tube **12** is only translated relative to the mold **22** and is not rotated when forming the indentations **30**. The indentations **30** are substantially parallel to the flow path of the fluid flowing through the tube **12**. Alternately, as shown in FIG. **6**, the mold **22** can form indentations **30** that are angled relative to the flowpath of fluid flowing through the tube **12**. In both these examples, the mold **22** is released from the tube **12** between successive crimps.

The amount of rotation and translation of the tube **12** relative to the mold **22** may be varied to produce a pattern of indentations **30** that creates a desired amount of turbulence in the fluid flowing through the tube **12**. For example, forming the indentations **30** at an angle relative to the flow path of the fluid through the tubes **12** can increase the amount of turbulence. One skilled in the art would know the desired orientation of the indentations **30** in the tube **12** to produce the desired turbulence.

The tubes **12** include the opposing end portions **26** that preferably have a substantially uniform circular cross-sectional shape. The cross-sectional shape of the end portions **26** may differ from the cross section of the tube **12**. That is, the cross-section of the end portions **26** corresponds to the cross-section of the desired connector. This allows the tube **12** to be easily attached to various other tubes, hoses, or other desired connectors. The end portion **26** may also be formed as different pieces and later attached to each of the tubes **12**.

FIGS. **7**, **8** and **9** show an alternate embodiment of the tube **12** of the present invention. In these embodiments, the mold **22** includes a roller (not shown) installed within the die **20**. The mold **22** is crimped on the tube **12**, and the tube **12** is translated relative to the mold **22** without releasing the mold **22** from the tube **12**. In this example, a continuous groove **34** is formed on the surface of the tube **12**. The groove **34** increases the surface area of the tube **12**, allowing more fluid to contact the walls of the tube **12** at a given time.

The mold **22** can include a plurality of rollers to form a plurality of substantially parallel grooves **34** on the tube **12**. The rollers contact the tube **12** and are continuously crimped on the surface of the tube **12** to form parallel grooves **34** as the tube **12** translates relative to the rollers.

As shown in FIG. **7**, one example tube **12***a* includes six grooves **34***a*. FIG. **8** shows another example tube **12***b* having five grooves **34***b*. FIG. **9** shows another tube **12***c* having four parallel grooves **34***c*.

FIG. **10** illustrates an alternate tube **12** including a substantially spiral shaped groove **38** formed on the wall of the tube **12**. A roller contacts the wall of the tube **12** as the tube **12** is both rotated and translated relative to the mold **22** to form a substantially spiral shaped groove **38** on the tube **12**. The roller is continuously crimped against the tube **12** while the tube **12** is both rotated and translated. The angle at which the roller is placed against tube **12** and the amount of translation and rotation of the tube **12** can be varied to produce the desired spiral shaped groove **38**. Alternately, several rollers can be employed.

Although a preferred embodiment of this invention has been disclosed, a worker of ordinary skill in this art would recognize that certain modifications would come within the scope of this invention. For that reason, the following claims should be studied to determine the true scope and content of this invention.

The invention claimed is:

1. A method of forming a tube comprising the steps of:
- positioning the tube in a first position relative to a mold, wherein an entirety of the mold is located outside of the tube;
- forming an indentation on the tube with a mold;
- releasing the mold from the tube; and
- moving the tube to a second stationary position relative to the mold, wherein the stop of forming and releasing occur after the step of positioning the tube in the first stationary position, and the step of moving occurs after the step of releasing, wherein the step of moving includes rotating and axially translating the tube relative to the mold.

2. The method as recited in claim **1** further including the step of repeating the step of forming an indentation when the tube is in the second stationary position.

3. The method as recited in claim **1** further including the step of repeating the step of forming an indentation when the tube is in the second stationary position, wherein the step of rotating includes rotating the tube relative to the mold between approximately 5 to 10° between each of the step of repeating.

4. A method of forming a tube, the method comprising the steps of:
- positioning the tube in a mold at a first position, wherein an entirety of the mold is located outside of the tube;
- forming an indentation on the tube with the mold;
- releasing the mold from the tube;
- axially translating the tube to a second position relative to the mold subsequent to the step of releasing the mold from the tube, wherein the tube rotates during the step of axially translating; and
- forming a second indentation on the tube with the mold.

5. A method of forming a tube, the method comprising the steps of:
- positioning the tube in a mold at a first position;
- rolling the tube with a roller in the mold to form an indentation in the tube such that the roller engages the tube;
- axially translating the tube from the first position to a second position relative to the mold, wherein the step of rolling the tube occurs during the step of axially translating the tube such that the roller continually engages the tube during the step of axially translating the tube; and
- releasing the mold from the tube after the step of axially translating the tube.

6. The method as recited in claim **5** further including the step of rotating the tube, wherein the step of rotating the tube and the step of axially translating the tube occur simultaneously.

7. The method as recited in claim **6** wherein the step of rotating the tube includes rotating the tube between 5 and 10 degrees.

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 9,149,847 B2
APPLICATION NO. : 10/584033
DATED : October 6, 2015
INVENTOR(S) : Jerry L. Holden

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

IN THE CLAIMS:

In claim 1, column 4, line 8; delete "tube" and insert --tube, the method--

In claim 1, column 4, line 9; after "first" insert --stationary--

In claim 1, column 4, line 12; delete "a" and insert --the--

In claim 1, column 4, line 15; delete "stop" and insert --step--

Signed and Sealed this
Fifteenth Day of March, 2016

Michelle K. Lee

Michelle K. Lee
Director of the United States Patent and Trademark Office